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ATTENUATION OF X-RAY IN MUSCLE AND ALVEOLAR BONE DURING MANDIBULAR PREMOLAR PERIAPICAL RADIOGRAPHIC PROCEDURE

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The main purpose of this study is to find out the degree of attenuation when the x-ray entrances the skin and reaches the film at the bone area near the mandibular premolar root apex. In this study we used thermaluminescent dosimeters (TLDs) to measure the entrance dose and exit dose directly at the area of interest and calculated the penetration value P. We also simulated the attenuation process and calculated the P value in similar conditions. The results indicate that the mean P value of direct measurement from patient is 0.071 ± 0.018 (60kVp, HVL=1.5mm Al), while that for theoretical calculation is 0.06458 at 27keV. We concluded that P value of direct measurement can match with the theoretical value and further studies in jaw bone density and other related portions is worthwhile.

Key word: dental radiographic image, attenuation, radiation dose

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The formation of radiographic image normally uses different receptors such as film or phosphor to record the radiation dose at different geographic areas which were attenuated by the object. Therefore, we can easily realize that the radiographic image inseparably correlates with the attenuation process when x-ray passes through the object[1]. When the patient was taking dental radiograph, the attenuation of x-ray by the periodontal structures was recorded at the same time. For instance when a patient takes the mandibular premolar radiograph, the x-ray begins to be attenuated when it enters the skin of the target area; then the x-ray will further be attenuated by cheek muscle, gingival, alveolar bone and tooth until it finally reaches the film. In the attenuation process, the x-ray was attenuated by different structures and tissues with various radiation doses on the different geographic areas of x-ray film. The radiation dose consequently becomes the radiographic contrast on the radiograph. Therefore, the amount of attenuation of x-ray from entrance on skin up to reception on the film can reflect the tissues and their thickness. The object of this study is to find out the ratio of exit dose to entrance dose when patients take mandibular premolar periapical radiograph and this ratio is called penetration (P)[2]. In this study, we used both the direct measurement method and the principle of radiological physics to get the P value of mandibular premolar periapical area and compared the difference between these two results.

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MATERIALS AND METHODS

1. Measurement of entrance dose and exit dose

The dosimeter used was the Harhsaw TLD-100 chips. The dimension of TLD chip is 3.1 × 3.1 × 0.98 mm, and each chip was enclosed in a 10 × 10mm polyester sacket to prevent contamination during manipulation. The reader was a Harhsaw Model 3500 TLD reader. The objects for direct measurement were the adult patients who needed lower second premolar periapical radiograph. There were 6 TLDs for each patient

to measure the radiation dose, 3 for detecting entrance doses and 3 for exit doses. The TLDs for detecting entrance dose (D_0) were attached to the skin at the center of the x-ray main beam. The TLDs for detecting exit dose (D) were attached to the lower one-third of the film at a distance of 1 cm from one another as shown in Fig. 1. The x-ray machine used in this study was a Sanko W60 type with the exposure condition of 60kVp and 0.5s. The typical half value-layer (HVL) was 1.5mm AL (equivalent to 27.31 keV)[3]. The radiographs were taken by the same photographer using parallel method, and the x-ray cone was set as closely to the patient's skin as possible. The penetration value (P) is defined as the ratio of exit dose to entrance dose, i.e., $P = D/D_0$.

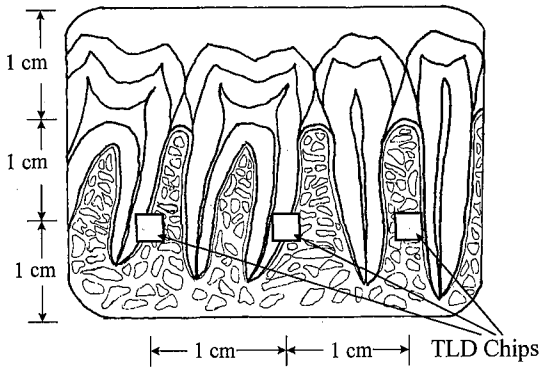

Fig. 1. Arrangement of TLDs for detecting the exit dose. The TLDs were attached to the lower one-third of the film at intervals of 1 cm.

2. Calculation of P value based on radiological physics principle

2.1 Linear attenuation coefficients (μ_E) of bone, muscle and fat

The mass attenuation coefficients of bone, muscle and fat are referred to the photon interaction coefficient table[1]. The products of mass attenuation coefficient (μ/ρ)and the density (ρ) of each material is the linear attenuation coefficient (μ). Then linear interpolation method was used to get the μ value of bone, muscle and fat from 20keV to 30keV at 1keV interval as listed in Table 1.

2.2 Simulation of attenuation process

The x-ray photon can interact with cheek, mandible bone (including cortical bone and trabecular bone), oral mucosa and tooth when the patient takes the periapical radiograph. To simplify this process, the x-ray photon reacts with a material composed of muscle, fat and bone. The thickness of this material is referred to by Nakajima et al. on the internal structure of Japanese mandible in 1992[4]. The percentage of these three components was measured by Mazess in 1992[5]. The settings of attenuation material thickness and percentage of these three components are listed in Table 2.

Table 1. The linear attenuation coefficient (μ_E) of bone, muscle and fat from 20keV to 30keV

Energy (keV)	Muscle	Fat	Bone
20	0.80808	0.48840	4.54245
21	0.76524	0.46666	4.24551
22	0.72240	0.44492	3.94858
23	0.67956	0.42319	3.65164
24	0.63673	0.40145	3.35471
25	0.59389	0.37972	3.05778
26	0.55105	0.35798	2.76084
27	0.50821	0.33624	2.46391
28	0.46537	0.31451	2.16697
29	0.42254	0.29277	1.87004
30	0.37970	0.27104	1.57311

Table 2. Tissue thickness and percentage of attenuation process in this study

Tissue	Thickness(cm)	Percentage(%)
Muscle	2	66.67
Fat	0.35	11.67
Bone	0.65	21.67
Total	3	100

* The bone substance typically is only 15-25% of total volume in the trabecular areas of skeleton, where the marrow is 75-85% (consisting of hematopietic cells and adipose cells); 50% of the total mass is water.

2.3 Algorithm of P value

The energy of x-ray from Sanko W60 (60kVp) is equivalent to 27keV monoenergetic beam[2]. According to the law of exponential attenuation, the algorithm of P value is:

$$P = \frac{I}{I_0} = e^{-\mu x} \quad \cdots\cdots(1)$$

where P is penetration, I the intensity of

attenuated x-ray, I_0 the intensity of x-ray before attenuation, μ linear attenuation coefficient of material, and X is the attenuation distance of material.

For the cheek and mandible bone, it was assumed that the x-ray passes through a material lapped of three layers-bone, fat and muscle. Then Eq.(1) can be applied to deduct the whole attenuation process.

$$\frac{I_{Muscle}}{I_0} = e^{-\mu_{Muscle} X_{Muscle}} \quad \cdots\cdots(2)$$

$$\frac{I_{Fat}}{I_{Muscle}} = e^{-\mu_{Fat} X_{Fat}} \quad \cdots\cdots(3)$$

$$\frac{I}{I_{Fat}} = e^{-\mu_{Bone} X_{Bone}} \quad \cdots\cdots(4)$$

Combine Eqs. (2)(3) and (4) one may obtain :

$$\frac{I}{I_0} = e^{-(\mu_{Muscle} X_{Muscle} + \mu_{Fat} X_{Fat} + \mu_{Bone} X_{Bone})} \quad \cdots\cdots(5)$$

Finally using the data from Table 2 and Eq. (5), one can get the calculated value of I/I_0.

RESULTS AND CONCLUSION

In the direct measurements, 14 patients, with 7 males and 7 females, participated in the dose measurements. The P value for male is 0.066 ± 0.022; for female it is 0.075 ± 0.014 and the mean is 0.071 ± 0.018. The P values calculated using radiological physics principle are 0.008741 at 20keV, 0.153085 at 30keV and 0.06485 at 27keV, respectively. The P values at other energies are listed in Table 3.

From the result, the P value from direct measurement is close to the P value at 27 keV from calculation. Because many factors such as energy of x-ray, buildup factor, density, and real thickness of tissues, etc. are present, these factors can affect the P value. Due to the settings of tissue thickness equivalent to the general human mandible bone composition, these made the calculation method to predict human mandible possible.

It is possible to use the direct measurement of P value and some calculated data to estimate the patient's jaw bone thickness or even the jaw bone density. If simple and stable radiation dose measurement method and calculation method are both applied, the total thickness of bone substance in the attenuation process under an ideal bone density may be obtained. This data can help a dentist to know more information about patient's jaw bone condition. However, it may produce discrepancy when the above formula applied to the individual patient as compared with direct measurement data, it involved statistical errors. To overcome this discrepancy, further study is needed in the future.

Table 3. The calculated values of penetration

Photon energy (keV)	Penetration (I/I_0)
20	0.00874
21	0.01163
22	0.01549
23	0.02063
24	0.02747
25	0.03658
26	0.04870
27	0.06485
28	0.08634
29	0.11497
30	0.15308

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下顎小臼齒根尖X光攝影時肌肉及骨骼組織對於X射線衰減作用之研究

邱品誠　印憶恆*　林立民*　張寶樹**

X光影像的產生是利用X光感應器如X光底片或儲存磷質，記錄X光受到被攝物體不同區域、不同程度之衰減以後到達感應器的輻射劑量。因此，我們可以知道X光影像是和X光在通過被攝體的衰減過程息息相關的。本實驗的目的是想要了解X光從射入皮膚到穿過下顎骨至到達底片的過程中大約衰減了多少比例的X射線，並比對兩種不同測量方法的差異。實驗中使用熱發光劑量計直接測量患者拍攝下顎小臼齒X光時皮膚的入射劑量以及底片上小臼齒牙根尖附近骨質部位的射出劑量算出兩者的比例。此外並使用放射物學公式推算相似條件下之入射劑量及射出劑量。實驗結果發現，以實際劑量測量法所算出之射出劑量-入射劑量比值（P值）平均爲0.07±0.018（條件爲60kVp，等效能量約爲27keV）；以放射物理學公式算出之P值在光子能量20keV時爲0.00874，光子能量27keV時爲0.06485，光子能量30keV時爲0.15308。由實驗結果可得知實際測量值介於理論值20keV及30keV之間，並且與預測的結果相近。本實驗的結果可作爲以底片或數位影像分析下顎骨骨質密度方面研究之參考。

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